Bob O. copy

CAPE HATTERAS WATER ASSOCIATION

CAPE HATTERAS, NORTH CAROLINA

Future Water Supply Study

September 5, 1995

CERTIFICATION

I hereby certify that this Future Water Supply Study for Cape Hatteras Water Association, North Carolina, was prepared by me or under my direct supervision.

Signed, sealed and dated this 8th day of September, 1995.

NORTH CAROLINA PROFESSIONAL SEAL 12532 ENGINEER IAN CHARLES WATSON

By: ______________________
IAN C. WATSON, P.E.
Reg. No. 12532

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CAPE HATTERAS WATER ASSOCIATION FUTURE WATER SUPPLY STUDY

Introduction

Subsequent to the construction and testing of the first brackish water test well, TW-1 (Figure 1). Boyle Engineering Corporation (BEC) prepared a report for the Cape Hatteras Water Association (CHWA) which summarized the results of the test and the resultant assessment of the cost of water from a Reverse Osmosis (RO) plant constructed to process the well water (Brackish Water Exploration Test Well – Final Report, June 2, 1995). As recommended in the letter transmitting this report to CHWA, a second test well program was proposed, prior to embarking on a costly hydrogeologic investigation designed to confirm and reinforce the preliminary RO process design assumptions. The recommendation was accepted, and TW-2 was constructed (Figure 1). As part of this program, the aquitard under the limestone formation was to be penetrated and the well extended into the underlying sandstone. This was accomplished, and while the test confirmed the superior productivity of the limestone aquifer, the chlorides found in TW-2 were more than twice the value of TW-1 chlorides. In addition, the sandstone aquifer chlorides exceeded 10,000mg/l, confirming the assumptions based on TW-1 results.

One explanation of higher chlorides was that TW-2 was significantly closer to the Atlantic Ocean than TW-1 and because of the apparently high transmissivity of the limestone, the water quality was more heavily influenced by the open seawater than TW-1.

As a result of this finding, and the identification of good quality shallow groundwater that could be used as blend water, a third test well, to be constructed as a designed well into the limestone unit only, was authorized by CHWA. This well was constructed on CHWA property on the North side of Hwy 12, not far from CHWA offices in Buxton.

As a parallel effort, CHWA also authorized their consulting hydrogeologist, Ralph C. Heath, to investigate the presence, longevity and safe yield of the lower permeable zone of the shallow aquifer system. Upon completion of these two parallel tasks, BEC was to review the data and conclusions, and re-evaluate the opinions of cost, both capital and O&M, prepared as part of the first test well program.

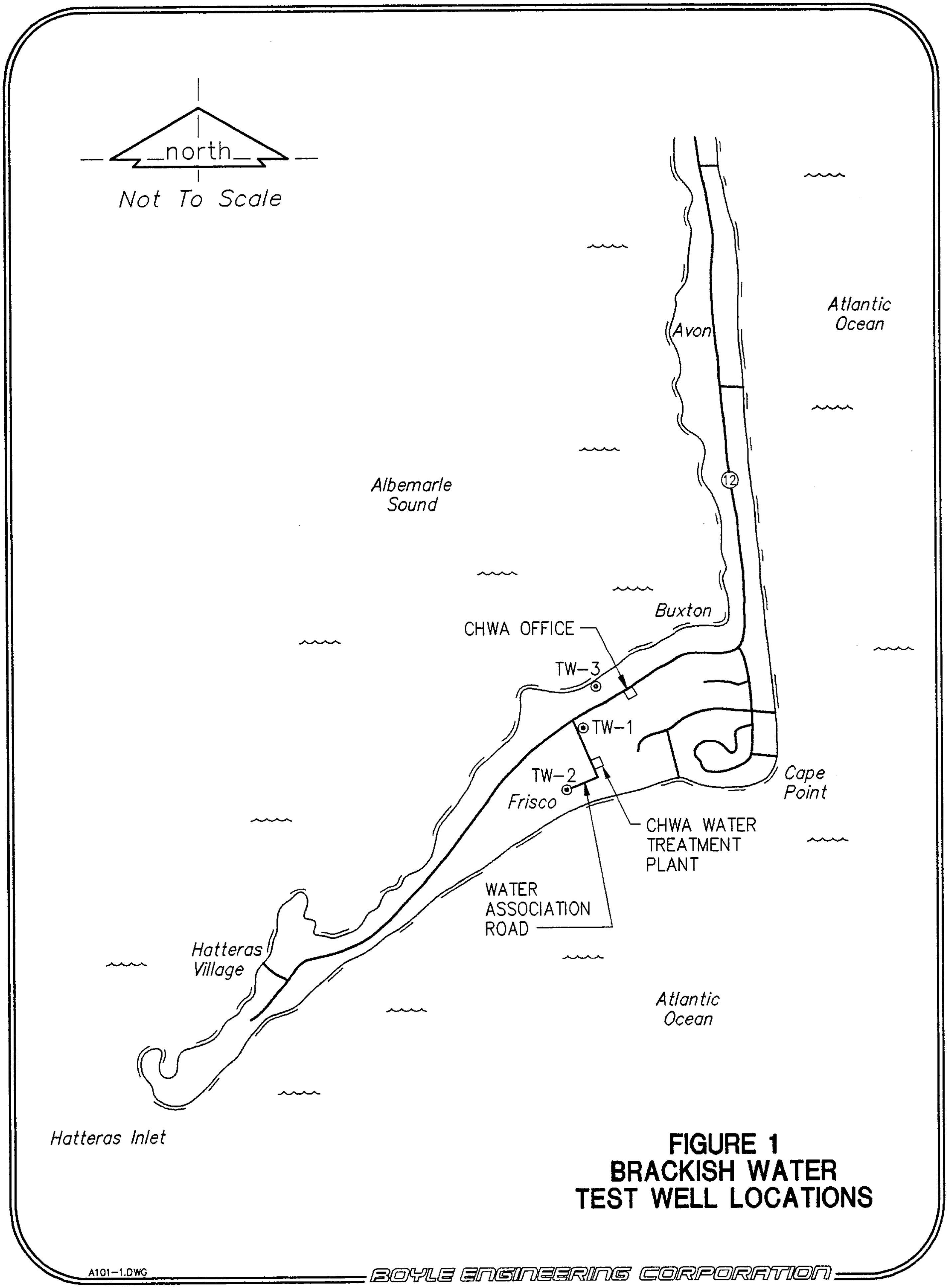

FIGURE 1
BRACKISH WATER TEST WELL LOCATIONS

Conclusions and Recommendations

A water treatment plant consisting of part brackish water desalting and part shallow groundwater treatment appears technically feasible for a lower Hatteras Island water supply, based on current knowledge of the brackish limestone aquifer. Future viability of brackish water desalting can be reinforced by additional groundwater exploration. A treatment plant capable of meeting near term summer average day demand, and 5-year additional demand can be constructed for about $7.5 million. The cost to produce blended water from this facility, not including labor, distribution and overhead costs is about $0.80/kgal. This cost is predicted to increase to about $0.95/kgal in the future, assuming current membrane performance improvements continue. All costs are based on 1995 dollars.

In order to support such a facility, it is recommended that the following actions are taken.

1. Continue to look for supplemental sources of relatively low TDS brackish water.
2. Continue to increase basic knowledge of the limestone aquifer characteristics.
3. Continue investigation into the optimum method of treating the shallow groundwater.
4. Plan to pilot test the limestone aquifer water with currently available ultra-low pressure membranes, to define operating characteristics and limitations.
5. Continue to investigate shallow groundwater treatment methodologies, and pilot test as appropriate.

Discussion of Options

As discussed in the first BEC report, the proposed RO plant was conceptualized on a reasonably conservative basis. It was projected that the feedwater TDS would stabilize at about 10,000 mg/l, with chloride concentration approaching 6,000 mg/l. The recovery was kept low, at 60%, for two reasons: first, the operating pressure required for higher recovery, and the resultant power cost could not be justified based on the apparent availability of groundwater; and second, the concentration of the waste stream needed to be kept as low as possible for discharge permitting reasons.

Both of these constraints are still valid. However, because of the potential for blending good quality shallow ground water, the stress on the limestone aquifer will be reduced, as will the volume of concentrate. Therefore, if future water quality permits, a higher recovery and thus lower RO feed pump power could result, at least initially.

Review of the report by Ralph Heath (Report Related to Modification of the Frisco Wellfield of CHWA, August 1995) reveals two significant conclusions: first that the water pumped from the lower zone of the shallow aquifer is of good quality with low iron and organic content, but that the quality will deteriorate as a downward flow is induced in the upper zone; and second, that the rate of deterioration will be rapid, possibly reaching near equilibrium with the upper zone in less than one year. As a result, the intended blend water may possibly be enriched in iron and organic materials, making it similar to the current raw water supply. In this state, it cannot be blended with RO permeate without additional treatment.

The report on the brackish water tests wells (Summary of Preliminary Reverse Osmosis Test Wells Construction for CHWA, Buxton, NC, by Missimer International, August 1995) substantially supports the program's earlier findings concerning productivity of the limestone formation. A potential sustainable yield of 4.0 mgd appears to be available, given appropriate wellfield design, and proper management.

The quality (both current and future) is more difficult to predict, but TW-3 did exhibit quality indicators more closely allied to TW-1 than to TW-2. If in fact the chloride concentration in the water contained in the upper zone of the limestone decreases as the distance from the Atlantic increases, then wells along Hwy 12 would appear to be the optimum placement. It is anticipated that this orientation will minimize salt water intrusion.

The capacity of the RO plant proposed for CHWA future water supply has been defined as 3.0 mgd at full size. Initially, based on current pumpage data, and an initial estimate of the demand for water when it again is available, an initial capacity of 2.4 mgd was proposed in the BEC June 2 report. This was based on 3x800,000 mgd RO units. If the supply was provided by **blended** production (i.e. using shallow ground water with hardness and alkalinity to blend with RO permeate), a flow sheet as shown in Figure 2 could result, and the RO portion of the system would be smaller. The RO system would start at 1.2 mgd, expandable to 1.8, with an initial 0.6 mgd of blend, expanded to 1.2 mgd.

R.O. 1.2 MGD
Shallow blend 0.6
1.8
Then - R.O. 1.8 MGD
Blend 1.2 MGD
3.0 MGD

Table 1 is reproduced from the Heath Report, and compares the quality of the water from the upper and lower zones of the shallow aquifer. The values for iron (Fe) and total organic carbon (TOC) are significantly lower than in the upper zone, at the west end of the wellfield. However, recent data indicates that at the east end, the quality is more similar to the existing pumped zone. Assuming that the iron, manganese and TOC can be controlled at an appropriate level by "conventional treatment", the RO permeate/shallow zone blend ratio can be controlled by other parameters. In this case, it is recommended that hardness and alkalinity be used, and that each be established at 100 ppm as $CaCO_3$ in the blended water.

Table 1

Partial Chemical Analysis of Water from the Frisco Wellfield

Constituent or Property	Wellfield Raw Water[1]	"New" Well No. 3[2]
Alkalinity, mg/l	272	260
Chloride, mg/l	43	34
Iron, as Fe, mg/l	3.5	0.15
Manganese, as Mn. mg/l	0.08	0.035
Apparent color, units	200	15
Total hardness, as $CaCO_3$ mg/l	308	268
Total dissolved solids, mg/l	440	356
Total organic carbon, as C, mgl	19	3.2
Turbitity, NTU	2	<1

[1]Analysis by Oxford Laboratories, Wilmington, NC. All determinations, except those for total dissolved solids and total organic carbon made on sample collect on June 6, 1990. Total dissolved solids are for a sample collected in 1993 - date unknown. Total organic carbon is for a sample collected on June 29, 1995

[2]Analysis by Oxford Laboratories of sample collected on October 3, 1994

Source: Report Related to the Modification of the Frisco Wellfield of the Cape Hatteras Water Association; Ralph E. Heath; August 1995

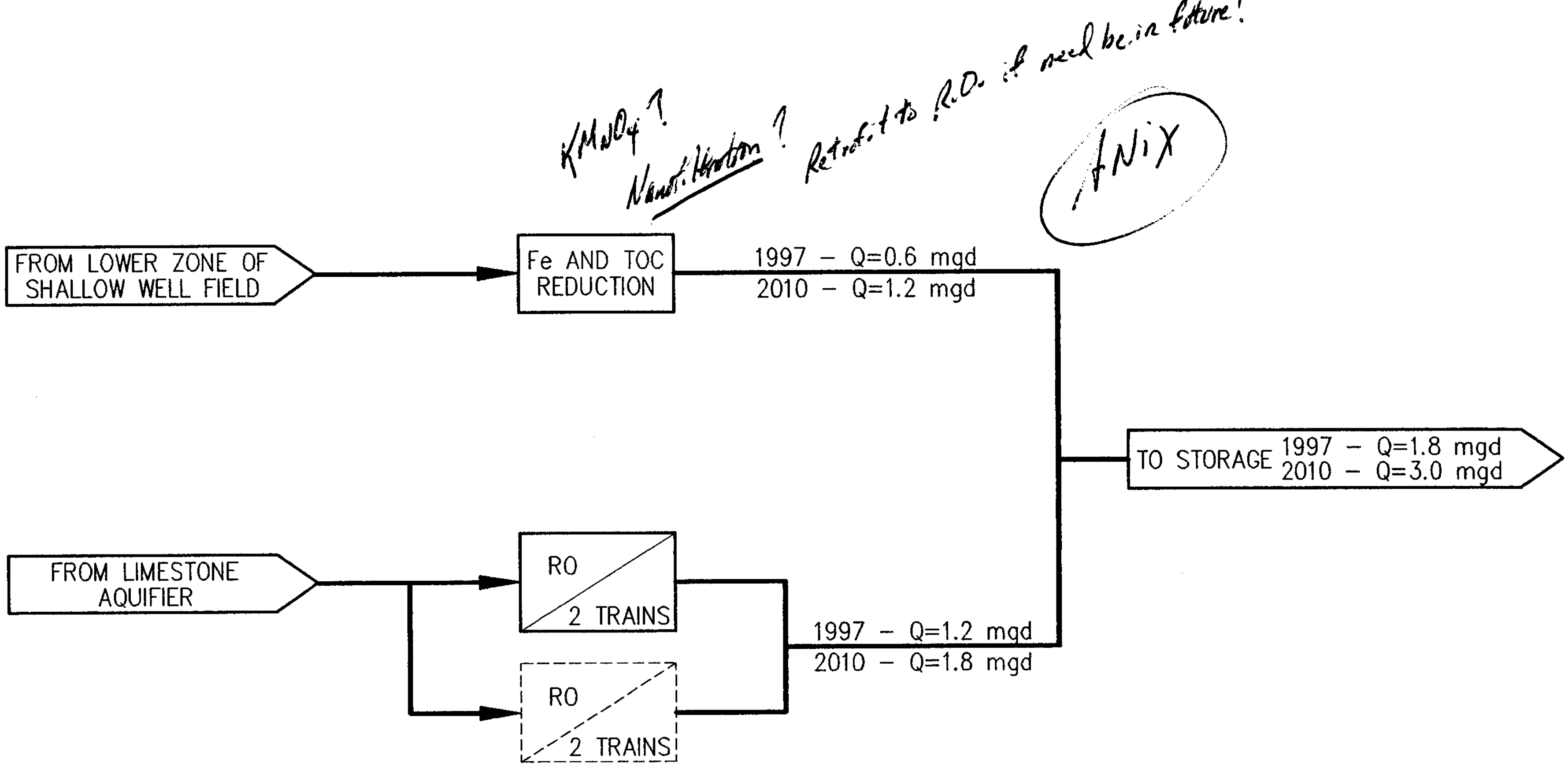

FIGURE 2
PROPOSED CAPE HATTERAS SYSTEM
FLOWSHEET FOR BLENDED PRODUCT

A101–2.DWG

BOYLE ENGINEERING CORPORATION

Since the BEC report of June 2, 1995, at least two membrane manufacturers have announced that the ultra-low pressure membranes discussed in that report are now commercially available. The rumored membrane price structure, at least initially, will place a premium of $200 to $300 per element on these devices. However, given the significant energy advantage of these devices, the conceptual RO plant discussed here and in the later cost section is assumed to use the new membranes, if not initially, then in the future. Initial process designs must be developed accordingly.

Table 2 compares the water quality in terms of the significant ions and parameters from each of the three limestone test wells. Also shown is the design point analysis used in the Boyle report on Test Well #1. It will be seen that an approximate doubling of the TDS was assumed, to represent the anticipated degradation in water quality.

Table 2
Comparison of Water Quality from Three Limestone Test Wells from Lab Reports

Ion or Property (3)	**TW-1**	**TW-2**	**TW-3(2)**	**TW-1 (1) Projected**
Calcium	81.65	341	219	384
Magnesium	82.0	512	341	82
Sodium	1882	4070	2270	3656
Potassium	40	47	78	40
Barium	—	—	0.41	—
Strontium	—	—	8.95	—
Iron	0.025	0.14	0.06	—
Bicarbonate	256	234	272	256
Chloride	3800	7800	4749	5782
Sulphate	156	667.5	166	862
Fluoride	0.78	1.16	—	0.8
Silica	17.2	19.7	19.4	17.2
TDS	5800	13280	8125	11080.8
pH	7.35	7.24	7.30	7.60
Temperature °C	20	20	20	20

(1) Ionic values used for membrane performance projections in the Test Well #1 report by Boyle, June 2, 1995

(2) Analysis by US Filter, August 1995.

(3) In mg/l or as noted.

From Table 2, it can be seen that the water quality found in TW-3, although better than TW-2 as expected, is higher in chlorides and TDS than TW-1. To properly estimate the cost of desalting this water, the process must be capable of accepting future conditions. Based on the location of TW-2 and potential future well sites, it is prudent to anticipate a worsening of quality with time. However, as wells are constructed along Hwy 12, the preferred alignment to the west, it is entirely possible that the limestone formation may terminate. But given the westerly direction, the source of well water that supplies Ocracoke may be encountered. This source is lower in chlorides than even TW-1.

Because of this possibility, a future plant raw water quality was constructed consisting of 75% TW-3 water, and 25% standard seawater. The resultant quality can be seen in Table 3.

Table 3
Actual and Projected Water Quality for TW-1 & TW-3

	TW-1		TW-3	
Ion — mg/l	**Pump Test**	**Projected**	**Pump Test**	**Projected**
Calcium	82	384	219	264
Magnesium	82	82	341	573
Sodium	1882	3656	2270	4342
Potassium	40	40	78	153
Barium	—	—	0.41	0.41
Strontium	—	—	8.95	8.95
Bicarbonate	256	256	272	240
Chloride	3800	5782	4749	8307
Sulphate	156	862	166	787
Fluoride	0.78	0.78	—	—
Silica	17.2	17.2	19.4	17
TDS	5,800	11,081	8,125	14,690
pH	7.35	7.60	7.24	7.40
Temperature °C	20	20	20	20

Based on the quality available from the desalting plant, a blended product water of less than 500 mg/l TDS, and with hardness and alkalinity approximately 100 mg/l each, as discussed previously, can be produced. The analysis of initial and future product are shown in Table 4.

This water was used to make projections using both the standard low pressure membranes, and the new ultra-low pressure products. Both membranes can produce a potable quality water from the design feedwater at 50% recovery, with a concentrate quality of about 29,000 mg/l TDS. Membrane area in addition to that required for initial operations will need to be added, the array will need to be changed from two-stage to single stage, and the concentrate volume will increase to 1.8 mgd. A small volume of wastewater of similar quality to the existing WTP discharge will be generated by the shallow groundwater treatment equipment. An estimate at buildout is 50,000 gpd. The relevant data can be seen in the "Conceptual RO System Evaluation" tables in Appendix A. The membrane projection data can be found in Appendix B.

Table 4
Blended Product Water Quality

Ion-mg/l	RO Permeate Initial	RO Permeate Future	Shallow[(1)]	Blend Initial[(3)]	Blend Future[(5)]
Calcium	1.4	2.1	92	31.6	38.1
Magnesium	2.1	4.5	8.8	4.3	6.2
Sodium	67.8	161.0	17	50.9	103.4
Potassium	2.9	7.1	2.6	2.8	5.3
Bicarbonate	11.1	13.3	287	103.1	122.8
Chloride	108.8	257.2	70	95.9	182.3
Sulphate	1.0	6.1	10	4.0	7.7
TDS[(6)]	214	451.6	487	292.6	465.8
TH	12	23.5	265	96.5	120.3
TAlk	9.1	10.9	235	84.5	100.7
pH	5.91	6.34	7.62	7.0[(4)]	7.3
CO_2	25.2	11.2	10.9[(2)]	20.4	11.1
LSI	—	—	—	-1.11	–0.68

(1) Based on Dare County Analysis - 7/18/95 - assumes treatment
(2) Calculated from pH and HCO_3
(3) Based on 2:1 ratio, permeate: shallow
(4) Calculated from CO_2 and alkalinity
(5) Based on 3:2 ratio, permeate: shallow
(6) TDS is "sum of the ions."

COUNTY OF DARE

KILL DEVIL HILLS, NORTH CAROLINA 27948

BOB ORESKOVICH
DIRECTOR
WATER DEPARTMENT

600 MUSTIAN ST.
PHONE (919) 441-7788

INTER OFFICE MEMO

To: Terry Wheeler, County Manager
From: Bob Oreskovich, Water Director
Subject: BOC Agenda - April 7, 1997
CHWA Engineering Studies
Date: April 3, 1997

At the Monday Board of Commissioners meeting, both Hobbs, Upchurch and Associates (HUA) (Eric Weatherly) and Boyle Engineering (Ian Watson) will present the results of the studies that have been completed recently to determine the feasibility of the initial design for water treatment, quantity and quality improvements proposed by Boyle Engineering in September of 1995.

Also, Jay Johnston will present findings of the Distribution System improvements study.

Both studies (cost $85,445) have validated the initial design proposals and both are within the budgeted amounts proposed that were given to Dave Clawson previously.

I. WATER QUANTITY/QUALITY STUDY

	Originally Proposed	*Updated Estimate*
Present groundwater (fresh) treatment	$540,000	$438,000

II. DISTRIBUTION SYSTEM IMPROVEMENT STUDY

	DIEHL & PHILLIPS (1995 Cost Estimates)	*HUA*
Phase I	$ 780,000	$3,263,130*
Phase II	$ 1,500,000	$ 965,640
Phase III	$3,770,000	$ 819,520
Phase IV	$1,650,000	--------
TOTAL	$7,700,000	$5,048,290

*Hobbs, Upchurch and Associates also suggests an option to Phase I which includes the upgrading of the lateral mains (streets off Hwy 12) at an additional cost of $2,846,350. Sammy Midgett, TJ Ketterman and myself feel this can be done with our distribution crews in-house. This, of course, could be done if additional funds are allocated to "Distribution Lines" yearly as is budgeted annually now. This would lessen the cost of the Distribution improvements from $7,894,640 (as HUA proposes) to $5,048,290 as staff proposes above.

HUA proposes the improvements in three phases. Phase I as soon as practical. Phase II in less than five years and Phase III in 2007. Water department staff request/recommend both Phase I and Phase II be done together in that by the time Phase I is completed, it will be about time to start Phase II.

The next step after the presentation Monday will be to approve the pilot study report as presented, if applicable, for it establishes the design of what we want to do quantity, quality and delivery wise on southern Hatteras Island. When approved, the next step will be the Board's approval and recommendation to proceed with the well exploration, ...if this requires formal approval? If so, then we should request the necessary paperwork for the Engineering services to begin the Preliminary Design Report of the Water Treatment Plant and appurtenances. Cost as proposed for the next step:

Missimer International (Exploration):	$215,000
Hobbs, Upchurch and Associates (PDR):	$ 64,840
Boyle Engineering (PDR):	$ 50,000

For your information.

cc: Dave Clawson, Finance Director

BOYLE ENGINEERING CORPORATION

Santa Rosa Office
131 Stony Circle, Suite 750, Santa Rosa, CA 95401-9522

TEL (707) 578-2370
FAX (707) 578-2395

RECEIVED 9-12-95

LETTER OF TRANSMITTAL

To:	Date: 9/08/95	Job Number: SR-H75-100-00
CAPE HATTERAS WATER ASSOC. Hwy 12] Buxton, NC 27920	Attn: Jim Coleman	
	RE: Future Water Supply Study	

WE ARE SENDING YOU:

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REMARKS:

Jim, I hope all is well. See you on Wednesday. I will be in the office Monday until about 2:30 pm PCT.

Copy To:
Bob Oreskovich, Water Director/COUNTY OF DARE
Hobbs, Upchurch & Associates

Signed: Ian C. Watson

Ian C. Watson, PE
Technical Director, Membrane Processes

Opinion of Cost

The proposed water treatment plant concept developed in this study has been conceived in an attempt to minimize the stress on and perhaps the deterioration of both the limestone and the lower zone of the shallow aquifer. The facility will need to be modified as the quality from each aquifer changes, and the cost of the blended water will increase with time.

Initially, two RO units, with ULP membranes in the first stage, LP membranes in the second stage and a boost pump between stages will be installed. With performance based on the initial water quality, these units will be designed to accommodate additions and modifications required in the future. The shallow water treatment plant will be installed as a single system, but with vessel redundancy. This treatment is assumed to be either manganese greens and filtration, ion exchange, or a combination of the two. The initial installation is priced at $0.75/gpd, with the future addition priced at $0.50/gpd. It is assumed that some of the existing ion exchange equipment can be retrofitted.

Energy recovery devices have now been included in the cost opinion for RO because the relatively high pressure and low recovery make such devices attractive for a brackish water system. Based on a 70% on-stream factor, the payback for energy recovery is expected to be about three (3) years.

		$M		
		Initial	Addition	Total
1.	RO equipment	1.25	0.50	1.75
2.	Blend treatment	0.45	0.30	0.75
3.	RO wells (3)	0.75	0.30	1.05
4.	Shallow wells (4)	0.18	0.18	0.36
5.	Raw water transmission (2)	0.50	0.25	0.75
6.	Finished Water Storage, 3mg	0.75	—	0.75
7.	High service pumping	0.25	0.15	0.40
8.	Treatment Plant Bldg (1)	0.75	—	0.75
	Opinion of Constructed Cost	4.88	1.68	6.56
	Contingency @ 20%	0.98	0.34	1.32
		5.86	2.02	7.88
	Legal, admin, engineering, etc. @ 25%	1.47	0.50	1.97
	Opinion of Project Cost:	7.33	2.52	9.85

The following cost assumptions were made in preparing the capital cost opinion.

1. Building cost at $100/sqf
2. The previous raw water transmission main cost remains valid. Part of the cost can be deferred until additional wells are needed for expansion in the future. The existing wellwater system is assumed to be used for future supply.
3. Five (5) RO wells are needed for the initial installation, with two (2) additional required for the future addition.
4. 18 shallow wells at 50 gpm will be required, 9 now and 9 in the future.

3?

4? previous page?

APPENDIX A

Conceptual RO System Evaluation

Cape Hatteras Water Association

Based on Pumped & Projected Water Quality from TW-3

Operating Parameter	Unit of measure	Initial Operation with **Hybrid** Membrane System	Future Operation with **Low** Pressure Membrane	Future Ops with **Ultra Low** Pressure Membrane
Feedwater flow, one RO unit	gpd	923,077	1,200,000	1,200,000
Permeate flow	gpd	600,000	600,000	600,000
Recovery	%	65	50	50
Permeate quality	ppm TDS	214	330	440
Est. blended product quality(1)	ppm TDS	487	379	466
Number of Membranes	ea	120	144	132
Prod'n per membrane	gpd/element	5000	4167	4545
Feed pressure 1st stage	psig	227	373	332
Interstage Pressure	psig	333		
Permeate backpressure	psig	8	8	8
Pressure allowance, fouling	psig	20	20	20
Feed pump suction pressure	psig	15	15	15
Misc. piping losses	psig	3	3	3
Feed pump boost pressure	psig	243	389	348

(1) Blended with treated shallow groundwater.

Conceptual RO System Evaluation

Cape Hatteras Water Association

Based on Pumped & Projected Water Quality from TW-3

Operating Parameter	Unit of measure	Initial Operation with **Hybrid** Membrane System	Future Operation with **Low** Pressure Membrane	Future Ops with **Ultra Low** Pressure Membrane
Feedpump efficiency	%	78	78	78
Interstage Pump efficiency	%	75		
Feedpump shaft power	hp	117	243	217
Interstage Pump power	hp	39		
Motor & VFD efficiency	%	88	88	88
Recovered power	hp	22	46	41
Net pump power	hp	134	197	176
Unit power	kwhr/kgal of permeate	4.53	6.67	5.97
Balance of plant	kwhr/kgal of permeate	2	2	2
Plant power	kwhr/kgal of permeate	6.53	8.67	7.97
Acid(93%)	ppm	0	0	0
	#/kgal of permeate	0.00	0.00	0.00
Scale Inhibitor	ppm	4.20	6.00	6.00
	#/kgal of permeate	0.05	0.10	0.10
Caustic Soda, 50%	#/kgal of permeate	0.62	0.40	0.40
Chlorine, @ 3ppm	#/kgal of permeate	0.03	0.03	0.03

Conceptual RO System Evaluation

Cape Hatteras Water Association

Based on Pumped & Projected Water Quality from TW-3

Cost Component	Unit Cost	Units	Initial Operation with **Hybrid** Membrane System	Future Operation with **Low** Pressure Membrane	Future Ops with **Ultra Low** Pressure Membrane
Power, $/kw-hr	0.07	$/kgal of product	0.457	0.607	0.558
Acid, $/#	0.10	$/kgal of product	0.000	0.000	0.000
Scale Inh., $/#	1.25	$/kgal of product	0.067	0.125	0.125
Caustic, $/#	0.22	$/kgal of product	0.136	0.088	0.088
Chlorine, $/#	0.20	$/kgal of product	0.005	0.005	0.005
Membrane, $/each	900	$/kgal of product	0.099	0.118	0.108
Cartridges, $/kgal	0.02	$/kgal of product	0.020	0.020	0.020
Cleaning, $/kgal	0.02	$/kgal of product	0.020	0.020	0.020
Opinion of Operating Cost			0.804	0.983	0.924

APPENDIX B

Initial Operation, Hybrid 1st stage

HYDRANAUTICS RO system design software -- v 5.6 (c) 1995 09-04-95
RO program licensed to: Ian Watson
Calculation created by: Ian C. Watson

Project name:	CAPE HATTERAS TW-3 95	Permeate flow:	415400.0 GPD
HP Pump flow:	641.0 GPM	Raw water flow:	923111.1 GPD
Feedwater temperature:	20.0 C (68F)	Permeate recovery ratio:	45.0 %
Raw water pH:	7.30	Element age:	3.0 years
Acid dosage, ppm (100%):	0.0 H2SO4	Flux decline coefficient:	-0.030
Acidified feed CO2:	25.2 PPM	3 yr salt passage increase:	1.4
Feed pressure:	227.4 PSI	Recommended pump pressure:	240.3 PSI
Average flux rate:	14.4 GFD	Feed water:	Well water

Pass	Feed Flow Pass GPM	Feed Flow Vessel GPM	Conc. Flow Pass GPM	Conc. Flow Vessel GPM	Beta	Conc. Press. PSI	Element Type	Elem. No.	Array
1	641.0	53.4	352.6	29.4	1.07	199.5	8040-UHY-ESPA	72	12x6

Ion	Raw water mg/l	Raw water CaCO3	Feed water mg/l	Feed water CaCO3	Permeate mg/l	Permeate CaCO3	Concentrate mg/l	Concentrate CaCO3
Ca	219.0	546.1	219.0	546.1	1.2	3.0	397.2	990.5
Mg	341.0	1403.3	341.0	1403.3	1.9	7.8	618.5	2545.1
Na	2270.0	4934.8	2270.0	4934.8	59.8	130.0	4078.3	8866.0
K	78.0	100.0	78.0	100.0	2.6	3.3	139.7	179.1
NH4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ba	0.4	0.3	0.4	0.3	0.0	0.0	0.7	0.5
Sr	8.9	10.2	8.9	10.2	0.0	0.1	16.2	18.5
CO3	0.2	0.3	0.2	0.3	0.0	0.0	0.4	0.6
HCO3	272.0	223.0	272.0	223.0	9.8	8.1	486.5	398.8
SO4	166.0	172.9	166.0	172.9	0.8	0.9	301.1	313.7
Cl	4749.0	6698.2	4749.0	6698.2	95.9	135.2	8556.1	12067.9
F	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SiO2	19.4		19.4		0.2		35.1	
TDS	8124.0		8124.0		172.2		14629.9	
pH	7.30		7.30		5.86		7.55	

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	2.1%	2.1%	4.4%
SrSO4 / Ksp * 100:	5.5%	5.5%	11.4%
BaSO4 / Ksp * 100:	356.5%	356.5%	732.5%
SiO2 saturation:	14.9%	14.9%	27.0%
Langelier Saturation Index:	0.29	0.29	1.04
Stiff & Davis Saturation Index:	-0.09	-0.09	0.42
Ionic strength:	0.16	0.16	0.30
Osmotic pressure:	86.3 PSI	86.3 PSI	156.4 PSI

These calculations are based on nominal element performance when operated on a feed water of acceptable quality. No guarantee of system performance is expressed or implied unless provided in writing by Hydranautics.

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Initial Operation, Hybrid 2nd stage

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Calculation created by: Ian C. Watson

Project name:	CAPE HATTERAS TW-3 95	Permeate flow:	186400.0 GPD
HP Pump flow:	355.6 GPM	Raw water flow:	512087.9 GPD
Feedwater temperature:	20.0 C (68F)	Permeate recovery ratio:	36.4 %
Raw water pH:	7.55	Element age:	3.0 years
Acid dosage, ppm (100%):	0.0 H2SO4	Flux decline coefficient:	-0.030
Acidified feed CO2:	25.2 PPM	3 yr salt passage increase:	1.3
Feed pressure:	333.0 PSI	Recommended pump pressure:	348.7 PSI
Average flux rate:	9.7 GFD	Feed water:	RO concentrate

Pass	Feed Flow Pass GPM	Feed Flow Vessel GPM	Conc. Flow Pass GPM	Conc. Flow Vessel GPM	Beta	Conc. Press. PSI	Element Type	Elem. No.	Array
1	355.6	44.5	226.2	28.3	1.05	309.4	8040-LHY-CPA2	48	8x6

Ion	Raw water mg/l	Raw water CaCO3	Feed water mg/l	Feed water CaCO3	Permeate mg/l	Permeate CaCO3	Concentrate mg/l	Concentrate CaCO3
Ca	397.2	990.5	397.2	990.5	2.2	5.4	623.3	1554.3
Mg	618.5	2545.1	618.5	2545.1	3.4	14.0	970.5	3993.7
Na	4078.3	8866.0	4078.3	8866.0	107.0	232.6	6351.3	13807.1
K	139.7	179.1	139.7	179.1	4.6	5.9	217.1	278.3
NH4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ba	0.7	0.5	0.7	0.5	0.0	0.0	1.2	0.8
Sr	16.2	18.5	16.2	18.5	0.1	0.1	25.5	29.1
CO3	0.4	0.6	0.4	0.6	0.0	0.0	0.6	1.0
HCO3	486.5	398.8	486.5	398.8	17.5	14.3	754.9	618.8
SO4	301.1	313.7	301.1	313.7	1.5	1.6	472.6	492.3
Cl	8556.1	12067.9	8556.1	12067.9	171.6	242.0	13354.8	18836.1
F	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SiO2	35.1		35.1		0.4		55.0	
TDS	14629.9		14629.9		308.2		22826.6	
pH	7.55		7.55		6.11		7.74	

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	4.4%	4.4%	7.8%
SrSO4 / Ksp * 100:	11.4%	11.4%	19.9%
BaSO4 / Ksp * 100:	732.5%	732.5%	1260.0%
SiO2 saturation:	27.0%	27.0%	42.3%
Langelier Saturation Index:	1.04	1.03	1.60
Stiff & Davis Saturation Index:	0.42	0.42	0.80
Ionic strength:	0.30	0.30	0.47
Osmotic pressure:	156.4 PSI	156.4 PSI	246.0 PSI

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Future Operation, Ultra Low Pressure

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Calculation created by: Ian C. Watson

Project name:	CAPE HATT TW-3 FUTURE	Permeate flow:	600000.0 GPD
HP Pump flow:	833.3 GPM	Raw water flow:	1200000.0 GPD
Feedwater temperature:	20.0 C (68F)	Permeate recovery ratio:	50.0 %
Raw water pH:	7.60	Element age:	3.0 years
Acid dosage, ppm (100%):	0.0 H2SO4	Flux decline coefficient:	-0.030
Acidified feed CO2:	11.2 PPM	3 yr salt passage increase:	1.4
Feed pressure:	332.5 PSI	Recommended pump pressure:	346.3 PSI
Average flux rate:	11.4 GFD	Feed water:	Well water

Pass	Feed Flow Pass GPM	Feed Flow Vessel GPM	Conc. Flow Pass GPM	Conc. Flow Vessel GPM	Beta	Conc. Press. PSI	Element Type	Elem. No.	Array
1	833.3	37.9	416.7	18.9	1.04	317.7	8040-UHY-ESPA	132	22x6

Ion	Raw water mg/l	Raw water CaCO3	Feed water mg/l	Feed water CaCO3	Permeate mg/l	Permeate CaCO3	Concentrate mg/l	Concentrate CaCO3
Ca	264.0	658.4	264.0	658.4	2.0	5.0	526.0	1311.7
Mg	574.0	2362.1	574.0	2362.1	4.4	18.0	1143.6	4706.3
Na	4343.0	9441.3	4343.0	9441.3	157.0	341.3	8529.0	18541.3
K	154.0	197.4	154.0	197.4	6.9	8.9	301.1	386.0
NH4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ba	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sr	8.9	10.2	8.9	10.2	0.1	0.1	17.8	20.4
CO3	0.3	0.5	0.3	0.5	0.0	0.0	0.6	1.0
HCO3	240.0	196.7	240.0	196.7	12.9	10.6	467.1	382.8
SO4	787.0	819.8	787.0	819.8	6.0	6.2	1568.0	1633.4
Cl	8307.0	11716.5	8307.0	11716.5	250.7	353.6	16363.3	23079.4
F	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SiO2	17.0		17.0		0.3		33.7	
TDS	14695.3		14695.3		440.3		28950.2	
pH	7.60		7.60		6.33		7.89	

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	7.7%	7.7%	18.2%
SrSO4 / Ksp * 100:	16.4%	16.4%	38.5%
BaSO4 / Ksp * 100:	0.0%	0.0%	0.0%
SiO2 saturation:	13.1%	13.1%	26.0%
Langelier Saturation Index:	0.60	0.60	1.46
Stiff & Davis Saturation Index:	-0.01	-0.01	0.58
Ionic strength:	0.30	0.30	0.59
Osmotic pressure:	156.5 PSI	156.5 PSI	312.6 PSI

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Future Operation, Low Pressure

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Project name:	CAPE HATT TW-3 FUTURE	Permeate flow:	600000.0 GPD
HP Pump flow:	833.3 GPM	Raw water flow:	1200000.0 GPD
Feedwater temperature:	20.0 C (68F)	Permeate recovery ratio:	50.0 %
Raw water pH:	7.60	Element age:	3.0 years
Acid dosage, ppm (100%):	0.0 H2SO4	Flux decline coefficient:	-0.030
Acidified feed CO2:	11.2 PPM	3 yr salt passage increase:	1.3
Feed pressure:	373.0 PSI	Recommended pump pressure:	390.9 PSI
Average flux rate:	10.4 GFD	Feed water:	Well water

Pass	Feed Flow Pass GPM	Feed Flow Vessel GPM	Conc. Flow Pass GPM	Conc. Flow Vessel GPM	Beta	Conc. Press. PSI	Element Type	Elem. No.	Array
1	833.3	34.7	416.7	17.4	1.07	359.0	8040-LHY-CPA2	144	24x6

Ion	Raw water mg/l	Raw water CaCO3	Feed water mg/l	Feed water CaCO3	Permeate mg/l	Permeate CaCO3	Concentrate mg/l	Concentrate CaCO3
Ca	264.0	658.4	264.0	658.4	1.5	3.7	526.5	1313.0
Mg	574.0	2362.1	574.0	2362.1	3.3	13.4	1144.7	4710.9
Na	4343.0	9441.3	4343.0	9441.3	117.6	255.6	8568.4	18627.0
K	154.0	197.4	154.0	197.4	5.2	6.7	302.8	388.2
NH4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ba	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sr	8.9	10.2	8.9	10.2	0.1	0.1	17.8	20.4
CO3	0.3	0.5	0.3	0.5	0.0	0.0	0.6	1.0
HCO3	240.0	196.7	240.0	196.7	9.7	8.0	470.3	385.5
SO4	787.0	819.8	787.0	819.8	4.5	4.7	1569.5	1634.9
Cl	8307.0	11716.5	8307.0	11716.5	187.6	264.7	16426.4	23168.3
F	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SiO2	17.0		17.0		0.2		33.8	
TDS	14695.3		14695.3		329.6		29060.9	
pH	7.60		7.60		6.21		7.89	

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	7.7%	7.7%	18.2%
SrSO4 / Ksp * 100:	16.4%	16.4%	38.5%
BaSO4 / Ksp * 100:	0.0%	0.0%	0.0%
SiO2 saturation:	13.1%	13.1%	26.0%
Langelier Saturation Index:	0.60	0.60	1.46
Stiff & Davis Saturation Index:	-0.01	-0.01	0.59
Ionic strength:	0.30	0.30	0.60
Osmotic pressure:	156.5 PSI	156.5 PSI	313.9 PSI

These calculations are based on nominal element performance when operated on a feed water of acceptable quality. No guarantee of system performance is expressed or implied unless provided in writing by Hydranautics.

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